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Short Communication

Effectiveness of Biochar as a soil amendment and plant productivity

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Abstract

Experiment was carried out at the district agriculture training centre in Ellapparmaruthankulam, Vavuniya district from November 2014 to March 2015 by Random Completely Block Design with eleven treatments and three replicates. Treatments were T_1 Control, T_2 paddy husk biochar, T_3 Gliricidia biochar, T_4 Neem biochar, T_5 50% of Urea and 100% of TSP and MOP with Paddy husk biochar, T_6 50% of Urea and 100% of TSP and MOP with Gliricidia biochar, T_7 50% of Urea and 100% TSP and MOP with Neem biochar, T_8 100% of Urea, TSP and MOP with Paddy husk biochar, T_9 100% of Urea, TSP and MOP with Gliricidia biochar, T_{10} 100% of Urea, TSP and MOP with Neem biochar and T_{11} 100% of Urea, TSP and MOP. Plant height andyield were measured. The soil samples were collected for analysis before planting and after harvesting to measure the pH, EC, CEC, available nitrogen, available phosphorous and exchangeable potassium. Statistical analysis was exploited using SAS 9.0 at 5% significance level. Treatments showed significantly ($p=0.0001$) difference in plant height and yield. The highest height and yield observed was observed in T_9 (38.61cm). T_6(3998.58kg/ha). pH was significantly decreased ($p=0.0001$) by biochar. The resulted EC ranged from 0.1 to 0.36dS/m. Incorporation of biochar significantly ($p<0.0001$) increased CEC, available nitrogen, available potassium and exchangeable phosphorous in all treatments. Highest CEC (14.28meq/100g) was observed in T_2, available nitrogen (1.41ppm) was observed in T_9. Available phosphorus (12.2ppm) and exchangeable potassium (51.35ppm) were observed in T_6. In addition to this, treatments which inorganic fertilizers incorporated with biochar (T_5-T_{10}) showed higher level of available nitrogen, available phosphorus and exchangeable potassium than other treatments. This study revealed that the biochar application as a soil amendment combine with inorganic fertilizer increased the plant production while increased soil productivity. This study could be helpful to farmers to adopt this technique in order to mitigate soil and environmental issues concerned in this district.

Keywords: Biochar, soil productivity, inorganic fertilizer, vavuniya.

Introduction

Synthetic inorganic fertilizers, pesticides and weedicides are being used to increase the productivity in order to feed rapid increasing population but this decrease the soil productivity as well as increase environmental pollution. Especially in northern part of Sri Lanka, Nitrate contamination of ground water has become a serious problem where intensified agriculture is being practiced. Due to the negative impacts caused by agrochemicals, the alternative farming techniques has to be introduced. Therefore this study suggests the alternative farming technique that would help to withstand the soil productivity without pollute the environment. The use of biochar as a soil amendment has been proposed as a means to simultaneously mitigate anthropogenic climate change whilst improving agricultural soil fertility[1]. It may help to reduce nutrient run-off from soil and the associated problems[2]. Biochar is the by-product of a thermal process conducted under low oxygen or oxygen-free conditions (pyrolysis) to convert vegetative biomass[3]. Chilli plant was selected to study the effectiveness of bio char on crop yields as chilli is one of the most important cash crops in this district. Objectives of this studies are i. to evaluate the effectiveness of the different biochar on chilli yield, ii. to evaluate the suitability of bio char and inorganic fertilizer on the yield of chilli and iii. to evaluate the soil productivity with different combinations of biochar and fertilizer.

Materials and methods

The experiment was carried out at the district agriculture training centre in Ellapparmaruthankulam, Vavuniya district. The soil of the district is highly fertile due to reddish brown earth, low humid clays and alluvial soil. The north east monsoon is the largest rainfall season for the Vavuniya district. And comparatively small rainfall due to southwest monsoon. The average rainfall for the last five years is 1548mm. The climatological conditions are suitable for cultivation.

Study was conducted from November 2014 to March 2015 by Random Completely Block Design (RCBD) with eleven treatments and three replicates. The land was prepared with the plot size of 0.9×1.8m. Biochar for Paddy husk, Neem and Gliciridia were prepared at experimental site and incorporated in to the top 5cm soil with the rate of 1kg/m^2 (1t/ha). Chilli was planted 3 days after applications of biochar with the spacing of 45x60cm. Recommended level of Triple super phosphate, Muriate of Potash and urea were applied as inorganic fertilizers. The treatments categorised according to the kind of biochar and quantity of fertilizer, field experiments were T_1 Control, T_2 Paddy husk biochar, T $Bioc_3$ Gliciridia biochar, T_4 Neem biochar, T_5 Urea 50% with Paddy husk biochar, T_6 Urea 50% with Gliciridia biochar, T_7 Urea 50% with Neem biochar, T_8 Urea 100% with Paddy husk har, T_9 Urea 100% with Gliciridia biochar, T_{10} Urea 100% with Neem biochar and T_{11} Urea 100%. Plant height, fruit weight and fruit numbers were collected for analysis and the soil samples were collected for analysis before planting and after harvesting to measure the pH (1:2.5 suspension method), electric conductivity (EC) (1:5 suspension method), cation exchange capacity (CEC) (ammonium acetate extracted method), available nitrogen (N) (Kjeldahl method), available phosphorus (P) (Olsen method) and exchangeable potassium (P) (Flame photometry method). Statistical analysis was performed using SAS 9.0 and mean separation was exploited by Duncan's mean separation technique (α=0.05).

Gliciridia and neem biochar was prepared by followings ways. Small one sided open drum and both sided open larger drum were taken. Small drum was filled with cut pieces of dried Gliciridia/neem and covered by metal cover. Small drum was inversely fixed in the floor as the metal cover was bottom side of the drum. The large drum was fixed around the small drum. Firewood was put in the gap between small and larger drum and burnt around for 90 minutes for gliciridia. But time taken for pyrolysis of neem was slightly different from the gliciridia as 120 minutes were taken instead of 90 minutes. Water was sprinkled to cool down and put off the presence of any glowing material. Finally, bio char was allowed to air dry, grained and packed into bags for field application. And paddy husk biochar prepared by following ways. A metal drum was cut at both ends and one end was attached with chimney which was made by metal. Lots of holes were created in the drum and it was fixed in a place as vertically. Firewood was burnt inside the drum up to enough heat was generated, dried paddy husk was heaped around the metal drum for 30 minutes and paddy husk was turned and mixed continuously to prevent over burning. After pyrolising, it was watered to cool down and put off the presence of any glowing material. Finally, it was allowed to air dried and packed into sacks in order to apply in to the field.

Results and discussion

Soil chemical parameters: The soil of the experimental site was classified as Reddish Brown Earth soil and the chemical analysis showed that the soil is low in fertile and slightly basic (Table-1).

Table-1: Soil chemical parameters before planting.

Soil Properties	Value
pH	7.79
EC	0.1 dS/m
CEC	7.8 meq/100g
Available N	0.91ppm
Available P	0.71ppm
Exchangeable K	13.45ppm

Table-2: Soil chemical parameters after harvesting.

Treatments	pH	EC (dS/m)	CEC (meq/100g)	Available N (ppm)	Available P (ppm)	Exchangeable K (ppm)
T_1 (Control)	7.34^{a}	0.1^{c}	8.44^{b}	0.92^{de}	7.4^{f}	12.61^{g}
T_2 (Paddy husk biochar)	6.89^{abc}	0.1^{c}	14.28^{a}	1.02^{abc}	8.5^{e}	21.30^{f}
T_3 (Gliciridia biochar)	6.86^{abc}	0.1^{c}	12.96^{a}	1.06^{fg}	8.3^{ef}	20.98^{f}
T_4 (Neem biochar)	7.09^{ab}	0.13^{bc}	13.36^{a}	1.02^{g}	7.7^{ef}	21.10^{f}
T_5 (Urea 50% with Paddy husk biochar)	6.47^{cde}	0.23^{ab}	14.04^{a}	1.13^{ef}	10.9^{bc}	37.14^{c}
T_6 (Urea 50% with Gliciridia biochar)	6.61^{bcd}	0.3^{a}	13.76^{a}	1.27^{bcd}	12.2^{a}	51.35^{a}
T_7 (Urea 50% with Neem biochar)	6.53^{bcde}	0.26^{a}	12.58^{a}	1.23^{cde}	10.8^{bc}	42.97^{b}
T_8 (Urea 100% with Paddy husk biochar)	5.94^{ef}	0.33^{a}	12.80^{a}	1.36^{ab}	11.3^{ab}	31.83^{d}
T_9 (Urea 100% with Gliciridia biochar)	$6.41b^{cde}$	0.33^{a}	12.46^{a}	1.41^{a}	9.6^{d}	38.71^{c}
T_{10} (Urea 100% with Neem biochar)	6.06^{de}	0.36^{a}	12.93^{a}	1.30^{bcd}	10.6^{bcd}	32.35^{d}
T_{11} (Urea 100 %.)	5.38^{f}	0.3^{a}	9.05^{b}	1.06^{gf}	9.9^{cd}	29.34^{e}

Note: Means with the same letter are not significantly different.

pH: Compared to the control value of pH 7.34, the application of any combination of biochar and Urea showed a significant reduction in pH where pH 6.0-7.5 is the ideal pH for most productive soil[4]. Especially 5.38 and 5.94 pH was observed in T11 and T8 which resulted acidic soil. However Neem biochar, paddy husk biochar and gliciridia biochar resulted nearly neutral pH 7.09, 6.89and 6.86 respectively.

EC: There are no significant changes observed in EC in treatments in paddy husk biochar and Gliciridia biochar with the control EC value 0.1dS/m. However neem biochar (0.13dS/m) showed a significant difference (p=0.0001). Treatments with combination of biochar and urea showed larger difference higher than 0.2dS/m when compared to the control treatment.

CEC: Significant difference (p =0.0001) was observed in CEC in all the treatments when compared to control (8.44meq/100g). CEC of the soil sample varied from 8.44 to 14.04meq/100g which is shown in Table-2. Application of biochar significantly increased CEC in all treatment. Paddy husk biochar (14.28meq/ 100gram) and paddy husk biochar with 50% urea combination showed the greatest difference in CEC compare to control. Greater surface ultimately leads to increases in CEC[5] thus paddy husk biochar has the greater surface area due to less weight of charged particles. The active surface hold ions which can raise the high CEC[6] where the paddy husk biochar applied. Although the treatment with 100% urea showed minimal change 9.05 meq/100g) with other treatments. CEC 5-15meq/100gram is the moderate CEC of soil which is normally satisfactory for agriculture purpose[4]. The nutrient availability could be affected by increasing cation exchange capacity and enhance nutrient retention[5].

Available N: The mineral nutrients, N, P and K are known to affect growth and yield of the chilli. The available N content of all treatments showed a significant increased compared with control (0.92ppm). Treatments with 100% urea and paddy husk biochar combination T_8 (1.36ppm), gliciridia with 100% urea (1.41ppm) and neem biochar with 100% urea (1.30ppm) are showed greater improvement than control because of application of the urea percentage is higher than other treatment. Although treatments with 50% urea and biochar combinations (T_5,T_6 and T_7) also showed more significant increase in available N ranging from 1.13-1.27ppm than the pure biochar treatments (T2,T3 and T4) which showed available N 1.02-1.06 ppm.

Available P: Application of bio char significantly increased available phosphorous (p value <0.0001) in all treatment compare to control. Highest amount of available P observed in treatment of gliciridia biochar combine with 50% of urea. Available P ranged from 7.4ppm to 12.2ppm (Table-2). According to the Table-2, Available P followed the same trend which similar to available N. Treatment using of biochar with fertilizer (T_5 to T_{10}) showed the highest available P than treatment on fertilizer alone (T_{11}) because of nutrient cycles and nutrient availability significantly affected by biochar with microbial activity[7]. Thus the microbial decomposition produce organic acids and ions which chealate with metals and preventing the phosphorous precipitatation and also helping for phosphorous solubility[8].

Exchangeable K: Significant difference (p=0.0001) observed between exchangeable K and treatments except control. Exchangeable K ranged from 12.61ppm to 42.97ppm (Table-2). Application of biochar significantly increased exchangeable K in all treatments compare to control. Highest amount of exchangeable K was observed the treatment using of Gliciridia biochar combine with 50% of N fertilizer (T_6). The reason could be increased available potassium under additional supply through application of inorganic fertilizer, the solubilisation action taken by organic acids which produced by microbial decomposition of soil microbes[8].

Plant height: Plant height is the observable parameters which help to assess the effectiveness of various treatments. Plant height after 133 days of planting of various treatments were measured (Table-3). There was a significant difference (p=0.0001) between treatments and plant height. Mean Plant height ranged from 25.32–38.61cm. Gliciridia biochar with 100% of urea (T_9) showed the highest growth when compare with other treatments because this treatment showed highest nitrogen availability (1.41ppm). There was no significant difference between T_1, T_2 and T_3but significant difference was observed between T_1 and T_4 because of the neem biochar application increased the plant growth. There was a significance difference between Application of paddy husk biochar in both treatments with 100% and 50% urea and also for the gliciridia biochar because the application of 100% urea affected the chili growth. But there is no any significance different between T7 and T10 where we used neem biochar. This result agreed with previous study by Abid Khan[9].

Yield: (p<0.0001) 150 to 650gram per plot. Whereas maximum yield was obtained in T6 (gliciridia with 50% urea) which is 648g/plot. T9 (gliciridia with 100% urea) also showed more than 600g/plot. However the treatment with biochar and fertilizer combination (T5 to T11) showed overall greater yield than pure biochar treatments (p<0.0001). Biochar has the potential to increase nutrient availability for plants[1]. With the increased nutrient availability bichar could enhance the growth and yield of plants[10]. Available N, P and exchangeable K (Table-2) were high in application of biochar with fertilizer (T_5 to T_{10}) which might have increased the height and yield of the chilli plants.

The number of fruits per 100 gram was obtained is given in Table-3. There is a significant difference observed in Fruit numbers. Maximum fruit number per 100 gram was observed in control and the minimum fruit number per 100 gram observed the using of gliciridia biochar with urea 100% (T_6). Fruit number dependent on canopy size and vigour of plants[9].

Table-3: Plant growth parameters.

Treatments	Height (cm)	Yield (gram/plot)	Fruit number per 100 gram
T_1 (Control)	25.33[e]	161.84[e]	62[a]
T_2 (Paddy husk biochar)	25.32[e]	180.32[e]	59[b]
T_3 (Gliciridia biochar)	28.93[de]	211.35[e]	57[ab]
T_4 (Neem biochar)	30.44[cd]	182.10[e]	52[b]
T_5 (Urea 50% with Paddy husk biochar)	32.78[bcd]	530.05[c]	56[b]
T_6 (Urea 50% with Gliciridia biochar)	37.28[ab]	647.77[a]	51[b]
T_7 (Urea 50% with Neem biochar)	35.22[abc]	570.24[bc]	59[ab]
T_8 (Urea 100% with Paddy husk biochar)	36.25[ab]	564.59[bc]	54[ab]
T_9 (Urea 100% with Gliciridia biochar)	38.61[a]	623.26[ab]	57[ab]
T_{10} (Urea 100% with Neem biochar)	34.08[abc]	523.56[c]	60[ab]
T_{11} (Urea 100 %.)	34.83[abc]	406.05[d]	59[ab]

Note: Means with the same letter are not significantly different.

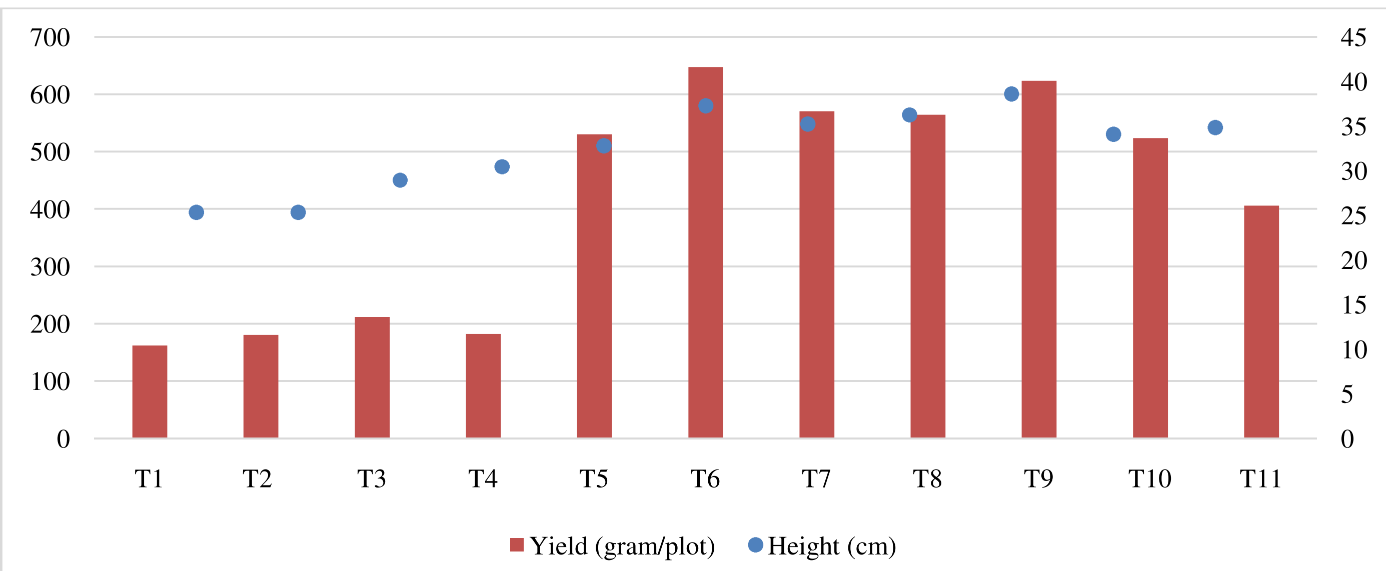

Figure-1: Yield and height of the chilli.

Conclusion

This study revealed that the biochar application as a soil amendment with inorganic fertilizer which significantly increased pH, EC, CEC, available nitrogen, available phosphorous, exchangeable potassium and plant yield. Incorporation of gliciridia biochar with 50% urea could be a better method to improve the soil and plant productivity with significant nutrition retention ability. This study could be helpful to farmers to adopt this technique in order to mitigate soil and environmental issues concerned in this district.

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